

E. Concepts and policies

E.3 – Sustainable use of the subsurface

THE ENFO KNOWLEDGE BASE TO SUPPORT EFFICIENT MANAGEMENT OF WASTE UTILIZATION ON SOIL

Vaszita, Emese^{1*}; Gruiz, Katalin¹; Siki, Zoltán², Feigl, Viktória¹; Klebercz, Orsolya¹; Ujaczki, Éva¹; Fekete-Kertész, Ildikó¹

¹Budapest University of Technology and Economics, Department of Applied Biotechnology and Food Science, 1111 Budapest, St. Gellért sq.4, Email^{1*}: emvaszita@mail.bme.hu, gruiz@mail.bme.hu

²Budapest University of Technology and Economics, Department of Geodesy and Surveying, 1111 Budapest, Műegyetem rkp. 3. K. mf. 26, Email: siki@agt.mail.bme.hu

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Abstract

Further to several international efforts in planning and establishing management systems or other IT (information technology) tools to support environmental management, a comprehensive Hungarian knowledge base and expert system, the ENFO = ENvironmental iNFOrmation, has been developed and designed combining the accessible IT tools and the up-to-date scientific and engineering knowledge on risk management of chemicals and contaminated sites. ENFO provides legal, scientific and engineering tools and embraces an expert system arranging the information in versatile forms, such as glossary, relational databases, picture galleries, e-courses, maps, etc. for a large variety of end-users, common people and professionals. The data are arranged according to the management levels and tasks in combination with the impacted elements of the environment such as chemical substances, environmental compartments and the exposed receptors. The knowledge base focuses on the environmental hazards and risks associated with the environmental compartments while supporting decision making on environmental management issues.

The informatics background of the ENFO knowledge base and web portal is a three-tiered architecture client–server design including a data tier, a logic tier and a presentation tier. The ENFO WEB portal integrates the Drupal content management system (CMS) and an existing database (MOKKA database), using MySQL (relational database management system based on Structured Query Language).

This paper concentrates on two key topics of the knowledge base: soil and waste, more specifically on waste utilization for soil remediation and amelioration, taking into account the risks and values of the waste and the risks and benefits of waste utilisation on soil. These topics were developed within the Hungarian SOILUTIL project = SOIL amelioration by innovative waste UTILisation technologies.

Introduction

Waste utilization for remediation of deteriorated and contaminated soil is a complex task requiring sustainable decisions. The decision making process on environmental management issues is usually supported not only by monitoring data, guidelines, and/or regulatory framework, but also by databases, knowledge bases, expert systems.

During the last 10 years the available volume of information is confusingly extensive to provide a thorough overview on every aspect of environmental management. Professionals, decision makers need systematically arranged information to take good decisions, to be able to select the best available environmental technologies, to evaluate management options and alternative risk reducing technologies.

Several efforts have been made worldwide to provide information for decision makers, professionals, stakeholders for the development and implementation of sound environmental policies on resource- and waste management. Statistical databases, providing quantitative data about waste

generation sources, waste categories, waste treatment types, soil types, soil degradation, as well as soil and ground water treatment technologies were prepared for various purposes during the last 10 years both in Europe and worldwide.

For example an electronic database (WasteBase, 2012) with historic information on waste and waste management in Europe was developed by the European Topic Centre's Data Center on Waste in 2002. Since 2006 the Data Centre on Waste is managed by Eurostat, the statistical office of the European Union. Therefore at present, the data on waste within the Eurostat dissemination database (EUROBASE) include the full range of publicly available data from Eurostat (Eurobase, 2013).

In addition to the EUROBASE various European countries have their own national waste databases (National databases, 2012), to support with information decision makers, scientists, engineers and the public.

Another example is the Australian Waste Database (CIRO, 2012) which collects information on waste quantities and composition to monitor the achievement of waste reduction targets and objectives in Australia.

The European Co-ordination Action for Demonstration of Efficient Soil and Groundwater Remediation (EURODEMO) initiated in 2004 (Eurodemo, 2012) has built a web-based database for demonstration projects in the field of soil and groundwater remediation. The database offers the opportunity to provide and access information on recent and ongoing pilot and demonstration projects for innovative remediation technologies. Users can search for remediation projects of interest, based upon a particular remediation type, contaminants of concern, geology or country of origin.

In parallel, the MOKKA Hungarian project (MOKKA, 2013) started putting the basis of an environmental risk management database (MOKKA database) including risk assessment methodologies, risk reduction methods and case studies.

Management of the extensive information in any database requires development of a knowledge base. A knowledge base is a special kind of database for knowledge management. Knowledge bases are founded on the concepts of experienced experts.

According to Maier (2007) knowledge management systems (generally IT based) are developed to support creation, capture of knowledge, storage, dissemination of information and decision making.

The technological tools of knowledge management and decision making are the expert systems (Leondes CT (ed) (2002). These expert systems are web-based, IT-aided dynamic systems, accessible and available for various user categories.

One of the recent examples of decision support expert systems is a Web-based Mining Waste Technology Selection site (ITRCWEB, 2013) developed by The Interstate Technology and Regulatory Council of US EPA (ITRC US EPA, 2013) to assist project managers in selecting an applicable technology, or suite of technologies, which can be used to remediate mine waste-contaminated sites. The site consists of decision trees (ITRCWEB Decision trees, 2013), overviews of applicable technologies, case studies where these technologies have been implemented and regulatory challenges. The decision trees, through a series of questions, guide users to a set of treatment technologies that may be applicable to that particular site situation. Each technology is described, along with a summary of the applicability, advantages, limitations, performance, stakeholder and regulatory considerations, and lessons learned and links to case studies where the technology has been implemented.

The Hungarian project consortium ENFO (ENFO, 2012) has developed a unique, comprehensive web based environmental knowledge base and expert system, the ENFO, which includes up-to-date scientific and engineering knowledge on risk management of chemicals and contaminated sites. The ENFO knowledge base and expert system supports decision-making with systematically organized and searchable information on environmental legislation, assessment and monitoring methods, risk and impact assessment tools, environmental remediation methods and a Decision Support Tool (DST) (Gruiz et al, 2013). The ENFO DST helps the user in finding the right solution on the regulatory, scientific and practical aspects of environmental management guiding the user to the solution through a decision tree, It works on a similar concept like the decision tree of the Web-based Mining Waste Technology Selection site developed by ITRC (ITRCWEB Decision trees, 2013) but the ENFO DST covers a broader spectrum of environmental topics.

The Hungarian SOILUTIL project (SOILUTIL, 2012) continued the development of the ENFO knowledge base and expert system focusing on the soil and waste topics, specifically waste utilisation on soil. Its main target is managing the sustainable utilisation of wastes for remediation and improvement of degraded and contaminated soil, putting on the balance the risks and values of the wastes and the risks and benefits of their utilization on soil, the potential hazard of a waste with the risks of its utilization on soil (Gruiz et al, 2010).

To manage the interaction between the Soil and Waste topics in the ENFO knowledge base according to the above concept a "matching" software is being developed. The software matches the utilizable characteristics and/or components of the waste (waste value) to the amendable characteristics,

parameters and/or missing components of the deteriorated soil to produce an efficiently remedied/amended soil. The knowledge base supporting the matching software is the ENFO-MOKKA waste characterisation and the soil amelioration/remediation technology database. Both contain information presented on purposefully prepared datasheets and are provided with search functions. The waste characterization data sheet includes information on the location and availability of the wastes, the value and hazard, as well as the potential usage and the associated risks at generic or site specific levels. The soil remediation technology database demonstrates via case studies the suitability of the wastes for soil remediation.

Objectives

The objective of this paper is to provide a general introduction of the ENFO environmental knowledge base and expert system, inclusive of its IT background, and to demonstrate its contribution to efficient and sustainable waste utilization on soil.

General description of ENFO Knowledge base

The ENFO knowledge base is a three-dimensional system with legal, scientific and practical engineering levels supporting users in acquiring information or in taking decisions in the field of environmental management, engineering and science. Within these levels the information are presented in versatile forms such as glossary, relational databases, maps, picture galleries, e-courses, etc., which represent sub-databases within the knowledge base and are available from the entry page of the ENFO portal, as shown in Figure 1 (Gruiz 2009).



Figure 1 Main menus of ENFO web portal and knowledge base

All these sub-databases are online readable and writable and optionally expandable. A tiered verification system ensures the professional control and management of the knowledge base. Registered users can upload and post relevant data and information, which become public only after verification. The pages of the portal and the services are available in English and Hungarian. However, the contents of the English and Hungarian pages are not identical. Not all publications have been translated into both languages yet. The information on Soil and Waste topics within the knowledge base can be found in all of the above mentioned menus.

The **glossary** contains the explanation and definition of materials, methods, procedures and other technical and scientific expressions associated with the topics of the ENFO knowledge base, organised in alphabetic order. An example of the Glossary is shown in Figure 2.

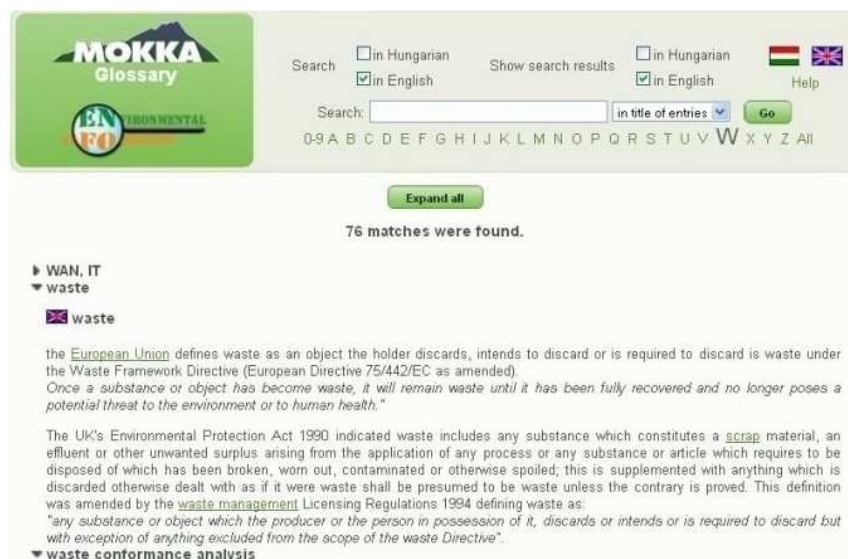


Figure 2 User Interface of the Glossary

The information visualised on **maps** are grouped into three units: two main units according to the general system of the ENFO knowledge base: Basic knowledge and Practical use and one unit, the interactive maps. The map types used for data visualisation are: digital maps, google maps and scanned (static) maps. The interactive map unit visualises geographic information system (GIS) data layers. GIS layers on soil degradation, soil types, waste disposal sites, in Hungary, and other information are accessible via the interactive map database.

Geographical distribution of the municipal solid waste deposits in Hungary visualised in the interactive maps database of the ENFO is shown in Figure 3. Additional data about every waste deposit are provided via overlay point data with pop up as shown in Figure.3.

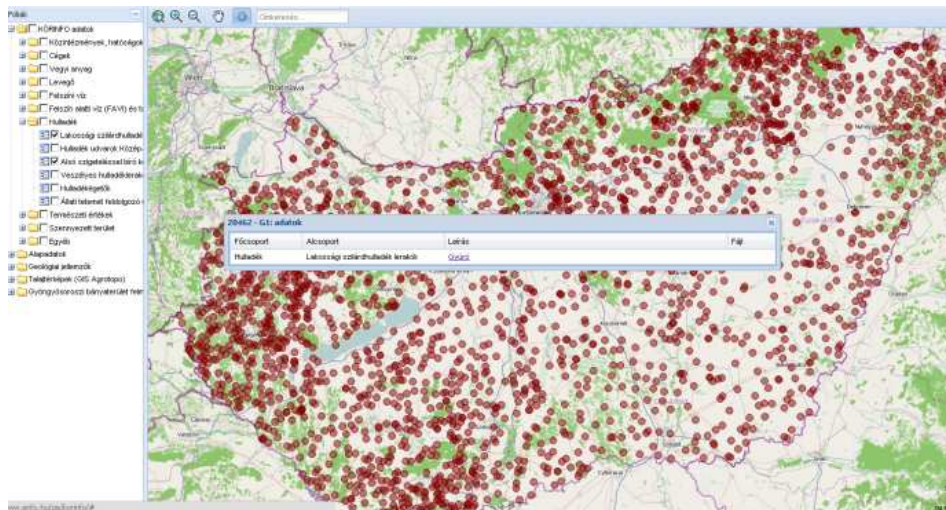


Figure 3 The ENFO interactive maps: Geographical distribution of the municipal solid waste deposits in Hungary and overlay point data with pop up

The **relational database** stores datasheets filled out online. The core of the ENFO expert system is the waste characterization database (waste/by-product survey database) and the soil amelioration/remediation technology database within the relational database. Both databases contain information presented on purposefully prepared datasheets and are provided with search engines.

The view of the list of some waste characterization datasheets, as shown in the database can be seen in Figure 4.

ENFO - MOKKA Database

Filter: 5.1 Waste / by-product survey

Text search: Search

Search by matrix Search datasheets in the following language: Hungarian

Waste / by-product survey (128 matches were found)

| Sheet id | Creator | Type | Name | State | Creation | Modification | Commands |
|----------|------------|---------------------------|------|-------|------------|--------------|----------|
| 812 | feigl | Waste / by-product survey | | ✓ | 2010-08-02 | 2011-11-15 | |
| 813 | feigl | Waste / by-product survey | | ✓ | 2010-08-02 | 2011-11-15 | |
| 821 | bartazsolt | Waste / by-product survey | | ✓ | 2010-08-09 | 2011-11-15 | |
| 822 | bartazsolt | Waste / by-product survey | | ✓ | 2010-08-09 | 2011-11-15 | |
| 825 | bartazsolt | Waste / by-product survey | | ✓ | 2010-08-10 | 2011-11-15 | |

Figure 4 List of waste characterisation datasheets in the waste/by-product survey database of the ENFO-MOKKA Database.

The waste characterization data sheet includes information on the location and availability of the wastes, the value and hazard, as well as their potential usage and the associated risks at generic or producer-specific levels as shown in Figure 5. The soil remediation/amelioration technology database

demonstrates via case studies the applicability/suitability of the wastes for soil remediation/amelioration of degraded soils.

Figure 5 Waste characterisation datasheet (first page)

The information in the **Photo** (galleries) and **E-learning** menus are arranged in two-dimensional thematic matrices where the environmental problems and compartments are combined with risk management, risk assessment and risk reduction methodologies and the relevant scientific bases. Figure 6 shows the thematic matrices of the Practical use photo gallery under the **Photos** menu. The matrix form enabled us to cover a large range of environmental management topics, while the graphical symbols of the matrix were planned to provide visual help for the user.



Figure 6 Matrix of the Practical use Environmental management photo gallery - content of the Risk Reduction technologies cell relevant to the Waste topic

Figure 6 shows also the detailed content of the risk reduction technologies section relevant to the waste topic, once clicking on the highlighted cell of the matrix.

The ENFO **DST**, similarly to the **Photos** and **E-learning** matrices of the ENFO knowledge base, was tailored to the specific knowledge levels of the system, including „Legal”, „Scientific” and „Practical” (concrete problem illustrated by practical examples) levels. Thus, the **DST** helps the user in finding the right solution on the regulatory, scientific and practical aspects of environmental management guiding the user to the solution through a decision tree. The ENFO **DST** covers a large spectrum of environmental topics, as shown in Figure 7. The main themes are chemical substances, air, soil and groundwater, waste, noise and vibrations, contaminated land. Figure 7 shows the user interface of the Practical matrix of the DST highlighting the cells that contain decision trees in connection with practical cases on the soil and waste topics.



Figure 7 User interface of ENFO DST: detail of the “Practical use” matrix showing the “Soil” and “Waste” cells

IT background of ENFO Knowledge Base

For managing the web portal and the knowledge base of ENFO, a three-tiered architecture client-server was designed, as shown in Figure 8 (Siki, 2009). The advantages of this three-tiered system are linearity and straightforward connections/topology.

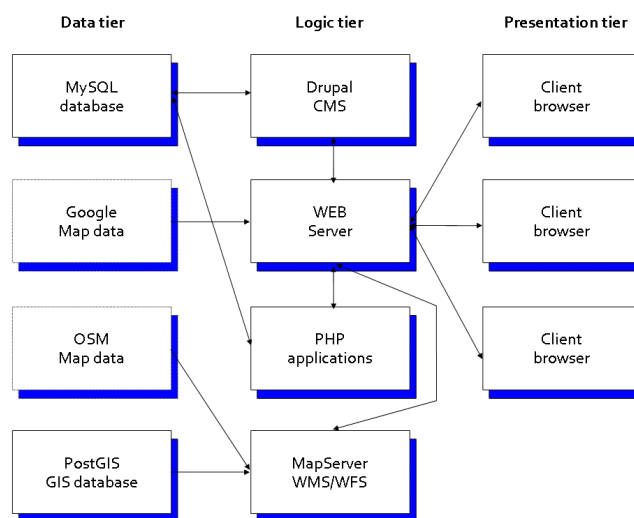


Figure 8 Three-tiered Architecture

In the data tier, remote and local databases are combined. In addition to our own databases, we use remote public map data, denoted by dashed border, as WEB map services.

In the center of the logic (application) tier the Apache WEB server can be found. All clients connect first to the Apache server, which dispatches the user queries to the other components/servers. Our WEB portal is managed by the Drupal content management system (CMS). Benefits of a CMS are separate design, structure and content, these three parts can be changed independently. Authorized users can extend the content of the WEB portal without having technical information about HTML and WEB technology. A number of Drupal extension modules are used to make the ENFO portal more attractive and comfortable (Eccher at al. 2005). For some tasks which cannot be solved in the CMS, extra components/servers are used and PHP and JavaScript codes were developed.

The presentation tier is the browser program (e.g., Firefox, IE, Google Chrome, Opera) used on the client side. JavaScripts run on the client computer to handle client-side events. AJAX (Asynchronous JavaScript and XML) (Crane and Pascarello 2006) technology is widely used to download data from the

server. In the interactive mapping applications, JavaScripts are used too. Currently, a single server is used for the database and the application tier, as the traffic is not yet too heavy for the presently applied quad core server. As the customers' number increases, the hardware background can be extended. Except the Google Maps API 3 only open source software (OSS) is used on the server side. The reason for this is not only to save money but to enjoy the benefits of open and extendable system and open standards.

Because of the different type and organization of the individual parts of the ENFO portal, different IT tools are used (Gruiz, and Siki, 2013):

- *Home, Photos (image catalogs), E-learning, Forum*: Drupal CMS, MySQL database;
- *Glossary*: MySQL database and home-made PHP and JavaScript code;
- *Risk management database*: MySQL database and home-made PHP and JavaScript code;
- *Digital maps*: PostGIS database, OpenLayers, GeoExt and home-made JavaScript.

Drupal CMS was customized to give an individual outlook (styles, colors, etc.) to the portal. Image catalogs and the forum use standard Drupal extension modules.

The software components are available on different operating systems (Windows, OS X, Unix/Linux), so the portal and database can be ported easily to other operating systems.

Software supported decision making tool for waste utilization on soil

A software supported decision making tool, a matching software system, is being developed by the SOILUTIL Hungarian project consortium to contribute to preliminary decisions on the sustainable, risk-based and efficient utilization of wastes for remediation of degraded and contaminated soil aiming at reducing, reusing and recycling various waste streams. This decision support tool works on the concept of matching the utilizable characteristics and/or components of the waste (waste value) to the amendable characteristics, parameters and/or missing components of the deteriorated soil to produce an efficiently remedied/amended soil.

The complex matching system contains navigation algorithms, leading the user to various decision points, where it offers further problem specific navigation possibilities. At the end of the problem specific routes, simple and combined search engines, GIS based software and other additional software tools are provided to the user to reach the final solution. This system matches the suitable wastes to the amendable soil in several steps, both at generic or site specific levels according to the requirements of the user.

To start navigation we have distinguished four user navigation cases for the software driven decision support

- (Gs x Gw) general soil amended with general waste
- (Gs x Cw) general soil amended with concrete waste
- (Cs x Gw), concrete soil amended with general waste
- (Cs x Cw), concrete soil amended with concrete waste,

where

- **Gw**: General waste, without any producer specific data, the waste is characterised in general on a waste characterisation datasheet of the ENFO-MOKKA database
- **Gs**: General soil, characterised with typical ranges of the characteristic parameters according to soil type
- **Cw**: Concrete waste: a site specific, producer specific waste, characterised in the waste datasheet of the ENFO-MOKKA database
- **Cs**: Concrete soil: The user will characterise the soil with his/her available data

The data requirement of the matching software is high. Therefore, the system is connected with the ENFO-MOKKA database including a great number of waste characterisation datasheets and soil remediation technology implementation case studies. The ENFO-MOKKA waste database provides the required information for the matching process regarding the parameters, components of the waste, hazards and risks of the waste and its utilisation on soil, geographical location of the waste etc.

Matching works according to the priority parameters of the degraded or contaminated soil and of the waste. The priority parameters of the degraded soil are grouped according to the main soil degradation cases focusing on the loss of nutrients, loss of organic matter, salinisation, acidification, sodification, compaction and pollution.

In the first step of matching the priority parameters of the degraded soil are compared with the optimum (theoretical) levels of the non-degraded soil.

In the second step, the matching waste or waste combinations (the closest to the optimal) are listed based on the requirements of the soil as compared with the optimal levels. The matching components/parameters are arranged according to a priority sequence.

The matching software system was planned to have an optimising feature able to provide a list of optimum waste mixtures and proportions to amend a certain degraded soil.

The control of the environmental risk upon adding the listed matching waste(s) to the soil has been considered in developing the software supported the decision tool, taking into account the Environmental Quality Criteria in force. The geographical location has been also considered in the design of the matching software, especially for the cases of Gs amended with Cw (Gs*Cw) and Cs amended with Cw (Cs*Cw). The spatial distribution of the waste deposits and of the soil type supports decisions in the field of waste and soil management.

Conclusions

The introduced ENFO system contributes to decision support in environmental management of chemical substances and contaminated land and it focuses on the sustainable and efficient waste utilization on soil.

The system is provided with legal, scientific and engineering tools and embraces an expert system arranging the information according to the management levels and tasks in combination with the impacted elements of the environment such as chemical substances, environmental compartments and the exposed receptors.

ENFO is a good example of combining IT tools (databases, photo galleries, e-courses, various maps, navigators and search engines) with scientific, engineering and management knowledge serving the systematic arrangement and easy search of information. All the sub-databases are online readable and writable and optionally expandable.

A tiered verification system ensures the professional control and management of the knowledge base.

The ENFO system focuses on the Waste and Soil topics and on the interaction between them in terms of waste utilisation on soil. The software supported decision making tool, called the matching software system, working on the concept of matching the utilizable characteristics and/or components of the waste (waste value) to the amendable characteristics, parameters and/or missing components of the deteriorated soil contributes to preliminary decisions on the sustainable, risk- based and efficient utilization of wastes for remediation of degraded and contaminated soil.

The ENFO knowledge base and its DST tool accommodates the requirements of various users including developers, researchers, degraded and polluted land owners, waste producers and disposers.

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